

5 What is Claimed is:

1. A protein comprising an amino acid sequence that codes for a variant protein of the lovE protein having at least one mutation selected from the group consisting of:
- 10 (a) a Group 6 amino acid residue mutated to a Group 2 amino acid residue at position 31;
- (b) a Group 3 amino acid residue mutated to a Group 5 amino acid residue at position 41;
- (c) a Group 4 amino acid residue mutated to a Group 2 amino acid residue at position 52;
- 15 (d) a Group 4 amino acid residue mutated to a Group 3 amino acid residue at position 52;
- (e) a Group 4 amino acid residue mutated to a Group 5 amino acid residue at position 73;
- 20 (f) a Group 1 amino acid residue mutated to a Group 4 amino acid residue at position 101;
- (g) a Group 1 amino acid residue mutated to a Group 3 amino acid residue at position 101;
- (h) a valine amino acid residue mutated to another Group 2 amino acid residue at position 111;
- 25 (i) a Group 4 amino acid residue mutated to a Group 2 amino acid residue at position 133;
- (j) a Group 3 amino acid residue mutated to a Group 2 amino acid residue at position 141;
- 30 (k) a Group 3 amino acid residue mutated to a Group 5 amino acid residue at position 141;
- (l) a Group 4 amino acid residue mutated to Group 6 amino acid residue at position 153;
- (m) a Group 4 amino acid residue mutated to a Group 5 amino acid residue at position 153;
- 35 (n) a Group 4 amino acid residue mutated to a Group 1 amino acid residue at position 281;
- (o) a Group 3 amino acid residue mutated to a Group 2 amino acid residue at position 367;

- 5 (p) a Group 3 amino acid residue mutated to a
Group 6 amino acid residue at position 367;
(q) a Group 1 amino acid residue mutated to Group
4 amino acid residue at position 389; and
(r) a Group 1 amino acid residue mutated to a Group
10 2 amino acid residue at position 389.
2. The protein of claim 1, wherein the variant protein
has a Group 6 amino acid residue mutated to a Group 2
amino acid residue at position 31.
- 15 3. The protein of claim 2 having the mutation F31L.
4. The protein of claim 1, wherein the variant protein
has a Group 3 amino acid residue mutated to a Group 5
20 amino acid residue at position 41.
5. The protein of claim 4 having the mutation Q41K or
Q41R.
- 25 6. The protein of claim 1, wherein the variant protein
has a Group 4 amino acid residue mutated to a Group 2
amino acid residue at position 52.
7. The protein of claim 6 having the mutation T52I.
- 30 8. The protein of claim 1, wherein the variant protein
has a Group 4 amino acid residue mutated to a Group 3
amino acid residue at position 52.
- 35 9. The protein of claim 8 having the mutation T52N.
10. The protein of claim 1, wherein the variant protein
has a Group 4 amino acid residue mutated to a Group 5
amino acid residue at position 73.

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11. The protein of claim 10 having the mutation C73R.
12. The protein of claim 1, wherein the variant protein has a Group 1 amino acid residue mutated to a Group 4 amino acid residue at position 101.
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13. The protein of claim 12 having the mutation P101S.
14. The protein of claim 1, wherein the variant protein has Group 1 amino acid residue mutated to a Group 3 amino acid residue at position 101.
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15. The protein of claim 14 having the mutation P101Q.
16. The protein of claim 1, wherein the variant protein has a valine amino acid residue mutated to another Group 2 amino acid residue at position 111.
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17. The protein of claim 16 having the mutation V111I.
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18. The protein of claim 1, wherein the variant protein has a Group 4 amino acid residue mutated to a Group 2 amino acid residue at position 133.
19. The protein of claim 18 having the mutation S133L.
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20. The protein of claim 1, wherein the variant protein has Group 3 amino acid residue mutated to a Group 2 amino acid residue at position 141.
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21. The protein of claim 20 having the mutation E141V.

- 5 22. The protein of claim 1, wherein the variant protein has a Group 3 amino acid residue mutated to a Group 5 amino acid residue at position 141.
23. The protein of claim 22 having the mutation E141K.
- 10 24. The protein of claim 1, wherein the variant protein has a Group 4 amino acid residue mutated to Group 6 amino acid residue at position 153.
- 15 25. The protein of claim 24 having the mutation C153Y.
26. The protein of claim 1, wherein the variant protein has a Group 4 amino acid residue mutated to a Group 5 amino acid residue at position 153.
- 20 27. The protein of claim 26 having the mutation C153R.
28. The protein of claim 1, wherein the variant protein has a Group 4 amino acid residue mutated to a Group 1 amino acid residue at position 281.
- 25 29. The protein of claim 28 having the mutation T281A.
- 30 30. The protein of claim 1, wherein the variant protein has Group 3 amino acid residue mutated to a Group 2 amino acid residue at position 367.
31. The protein of claim 30 having the mutation N367I.
- 35 32. The protein of claim 1, wherein the variant protein has a Group 3 amino acid residue mutated to a Group 6 amino acid residue at position 367.
33. The protein of claim 32 having the mutation N367Y.

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34. The protein of claim 1, wherein the variant protein has a Group 1 amino acid residue mutated to Group 4 amino acid residue at position 389.

10 35. The protein of claim 34 having the mutation P389S.

36. The protein of claim 1, wherein the variant protein has a Group 1 amino acid residue mutated to a Group 2 amino acid residue at position 389.

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37. The protein of claim 36 having the mutation P389L.

38. The protein of claim 1 selected from the group consisting of SEQ ID NO:42, SEQ ID NO:43, SEQ ID NO:44,
20 SEQ ID NO:45, SEQ ID NO:46, SEQ ID NO:47, SEQ ID NO:48, SEQ ID NO:49, SEQ ID NO:50, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:57, SEQ ID NO:58, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:62, SEQ ID NO:63, SEQ ID NO:64, and SEQ ID NO:65.

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39. A nucleic acid comprising a polynucleotide sequence encoding an amino acid sequence of a variant protein of the lovE protein having at least one mutation selected from the group consisting of:

- 30 (a) a Group 6 amino acid residue mutated to a Group 2 amino acid residue at position 31;
(b) a Group 3 amino acid residue mutated to a Group 5 amino acid residue at position 41;
(c) a Group 4 amino acid residue mutated to a
35 Group 2 amino acid residue at position 52;
(d) a Group 4 amino acid residue mutated to a Group 3 amino acid residue at position 52;
(e) a Group 4 amino acid residue mutated to a Group 5 amino acid residue at position 73;

- 5 (f) a Group 1 amino acid residue mutated to a
Group 4 amino acid residue at position 101;
(g) a Group 1 amino acid residue mutated to a
Group 3 amino acid residue at position 101;
(h) a valine amino acid residue mutated to another
10 Group 2 amino acid residue at position 111;
(i) a Group 4 amino acid residue mutated to a
Group 2 amino acid residue at position 133;
(j) an Group 3 amino acid residue mutated to a
Group 2 amino acid residue at position 141;
15 (k) an Group 3 amino acid residue mutated to a
Group 5 amino acid residue at position 141;
(l) a Group 4 amino acid residue mutated to Group
6 amino acid residue at position 153;
(m) a Group 4 amino acid residue mutated to a
20 Group 5 amino acid residue at position 153;
(n) a Group 4 amino acid residue mutated to a
Group 1 amino acid residue at position 281;
(o) a Group 3 amino acid residue mutated to a
Group 2 amino acid residue at position 367;
25 (p) a Group 3 amino acid residue mutated to a
Group 6 amino acid residue at position 367;
(q) a Group 1 amino acid residue mutated to Group
4 amino acid residue at position 389; and
(r) a Group 1 amino acid residue mutated to a Group
30 2 amino acid residue at position 389.

40. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the love
protein having a Group 6 amino acid residue mutated to a
35 Group 2 amino acid residue at position 31.

41. The nucleic acid of claim 40 having the mutation
F31L.

- 5 42. The nucleic acid of claim 39, wherein the polynucleotide encodes a variant protein of the love protein having a Group 3 amino acid residue mutated to a Group 5 amino acid residue at position 41.
- 10 43. The nucleic acid of claim 42 having the mutation Q41K or Q41R.
44. The nucleic acid of claim 39, wherein the polynucleotide encodes a variant protein of the love
15 protein having a Group 4 amino acid residue mutated to a Group 2 amino acid residue at position 52.
45. The nucleic acid of claim 44 having the mutation T52I.
- 20 46. The nucleic acid of claim 39, wherein the polynucleotide encodes a variant protein of the love protein having a Group 4 amino acid residue mutated to a Group 3 amino acid residue at position 52.
- 25 47. The nucleic acid of claim 46 having the mutation T52N.
48. The nucleic acid of claim 39, wherein the
30 polynucleotide encodes a variant protein of the love protein having a Group 4 amino acid residue mutated to a Group 5 amino acid residue at position 73.
49. The nucleic acid of claim 48 having the mutation
35 C73R.
50. The nucleic acid of claim 39, wherein the polynucleotide encodes a variant protein of the love

5 protein having a Group 1 amino acid residue mutated to a
Group 4 amino acid residue at position 101.

51. The nucleic acid of claim 50 having the mutation
P101S.

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52. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the lovE
protein having Group 1 amino acid residue mutated to a
Group 3 amino acid residue at position 101.

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53. The nucleic acid of claim 52 having the mutation
P101Q.

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54. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the lovE
protein having a valine amino acid residue mutated to
another Group 2 amino acid residue at position 111.

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55. The nucleic acid of claim 54 having the mutation
V111I.

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56. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the lovE
protein having a Group 4 amino acid residue mutated to a
Group 2 amino acid residue at position 133.

57. The nucleic acid of claim 56 having the mutation
S133L.

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58. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the lovE
protein having Group 3 amino acid residue mutated to a
Group 2 amino acid residue at position 141.

- 5 59. The nucleic acid of claim 58 having the mutation
E141V.
60. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the lovE
10 protein having a Group 3 amino acid residue mutated to a
Group 5 amino acid residue at position 141.
61. The nucleic acid of claim 60 having the mutation
E141K.
- 15 62. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the lovE
protein having a Group 4 amino acid residue mutated to
Group 6 amino acid residue at position 153.
- 20 63. The nucleic acid of claim 62 having the mutation
C153Y.
64. The nucleic acid of claim 39, wherein the
25 polynucleotide encodes a variant protein of the lovE
protein having a Group 4 amino acid residue mutated to a
Group 5 amino acid residue at position 153.
65. The nucleic acid of claim 64 having the mutation
30 C153R.
66. The nucleic acid of claim 39, wherein the
polynucleotide encodes a variant protein of the lovE
protein having a Group 4 amino acid residue mutated to a
35 Group 1 amino acid residue at position 281.
67. The nucleic acid of claim 66 having the mutation
T281A.

5 68. The nucleic acid of claim 39, wherein the polynucleotide encodes a variant protein of the lovE protein having a Group 3 amino acid residue mutated to a Group 2 amino acid residue at position 367.

10 69. The nucleic acid of claim 68 having the mutation N367I.

70. The nucleic acid of claim 39, wherein the polynucleotide encodes a variant protein of the lovE
15 protein having a Group 3 amino acid residue mutated to a Group 6 amino acid residue at position 367.

71. The nucleic acid of claim 70 having the mutation N367Y.

20 72. The nucleic acid of claim 39, wherein the polynucleotide encodes a variant protein of the lovE protein having a Group 1 amino acid residue mutated to Group 4 amino acid residue at position 389.

25 73. The nucleic acid of claim 72 having the mutation P389S.

74. The nucleic acid of claim 39, wherein the
30 polynucleotide encodes a variant protein of the lovE protein having a Group 1 amino acid residue mutated to a Group 2 amino acid residue at position 389.

75. The nucleic acid of claim 74 having the mutation
35 P389L.

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76. The nucleic acid of claim 39 selected from the group consisting of SEQ ID NO:66, SEQ ID NO:67, SEQ ID NO:68, SEQ ID NO:69, SEQ ID NO:70, SEQ ID NO:71, SEQ ID NO:72, SEQ ID NO:73, SEQ ID NO:74, SEQ ID NO:75, SEQ ID NO:76, 10 SEQ ID NO:78, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:82, SEQ ID NO:83, SEQ ID NO:84, SEQ ID NO:86, SEQ ID NO:87, SEQ ID NO:88, SEQ ID NO:89, and SEQ ID NO:90.